TITLE: Pulmonary Function in a Diving Population Aged Over 40 Years Old: A Cross-Sectional Study

PULMONARY FUNCTION IN A DIVING POPULATION AGED OVER 40 YEARS OLD: A CROSS-SECTIONAL STUDY.

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ABSTRACT: Professional military divers are exposed to high pressure levels during long time. This high pressure is going to have an effect over the diver and over the respiratory mixture that is going to breath. The consequences of this high pressure level are the following: High oxygen partial pressure, an increase in the density of the mixture that will be proportional to the depth. All these different aspects can produce modifications in the pulmonary volume and flows that can be observed by sypirometric test. OBJECTIVE: To evaluate the pulmonary function and the mechanism of pulmonary adaptation of a group of military divers overs 40 years old by a spirometric test. MATERIAL AND METHODS: A group of 23 males professional military divers who belong to the CENTRO DE BUCEO DE LA ARMADA (CARTAGENA-SPAIN). 8 of them were smokers and 15 were nonsmokers. We studied the following parameters: FVC, FEV1, FEV1/FVC, FEF 25-75, FEF75-85. RESULTS: FVC% (104.87), FEV1% (98.60), FEV1/FVC% (77.52), FEF 25-75% (90.87), FEF 75-85% (82.65). CONCLUSIONS: Divers aged over 40 years old show larger lung capacities than normal population, whereas parameters which indicate airway obstruction are decreased. This fact leads to consider the presence of an asymptomatic obstruction of small airways.

INTRODUCTION

During the performance of their professional activity, divers are exposed to an environment for which they are not physiologically prepared. The continuous action of various factors favours the appearance of changes in different organic structures. These changes, although unable to affect divers' health in an immediate way, can influence their quality of life in the long term.

As regards lungs, the effects from diving are conditioned by exposure to a number of elements which are inherent in the subject's activity. Among these, we emphasize: the continuous effect of changes in pressure, the use of diving apparatus with the different breathing mixtures, the surface tasks, the years of professional activity, the maximum depth reached, and the presence of diving accidents that required recompressive treatment. On the other hand, there exist other factors, which we call accessory. They are not exclusively referred to divers, though can accelerate or retard lung disease. These factors are smoking and sports practice.

The stay in hyperabic environments consists of two phases: one of compression, involving solution of the inert gases that form the gaseous mixtures into the various organic tissues, according to Henry's law, and a posterior phase of decompression during which the dissolved gases change back into the gaseous state, being eliminated by respiration. In order to prevent inert gas bubbles from being formed during decompression, the return to surface is made following decompression tables. Occassionally, despite decompression being carried out adequately, inert gas microbubbles are formed. On their vascular itinerary, these microbubbles shall be caught, filtered and eliminated by the pulmonary alveocapillary system (10), or shall cause a transitory sensation of breathing difficulty due to a state of restrictive respiratory insufficiency (8).

The use of either open, semiclosed or closed circuit divng apparatus provides a number of benefits such as the possibility of performing prolonged immersions, at higher depths, and of using gaseous mixtures different to atmospheric air (pure oxygen, heliox or nitrox). However, diving equipment also imposes several restrictions on the respiratory system, namely:

-Increase in breathing work, owing to: a rise in the density of the breathing mixtures, as well as to a reduction in lung volume and to an increase in the dead space. All these factors will determine a type of respiration in which tidal volume is increased and frequency diminished.

- Inversion in the respiratory pattern, because of the resistance imposed by the regulator that determines that expiration plays a predominant role over inspiration. This implies greater fatigue both for the expiratory and the inspiratory musculatures (13).

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- Toxic effect of certain gases such as oxygen as it is breathed at high partial pressures, either acutely or chronically.

- Modifications to pulmonary capacities and volumes: During immersions, a decrease in vital capacity, as well as in expiratory reserve volume and in residual volume takes place. (13) Increase in static lung volumes, attributed to the breathing of dense gases (1,19) and a decrease in dynamic volumes after immersions. (4,18,21)

The whole activity of divers is not carried out underwater: an important part of their assignments consists of other surface tasks which are not exempt from danger as far as respiratory system is concerned. Among them, we emphasize: welding activities, involving inhalation of toxic fumes and gases, and the stay in confined environments where different pollutants can accumulate.

The aim of this study was to check, through the performance of spirometric techniques, the pulmonary function and the mechanism of respiratory adaptation of a group of military divers whose principal characteristic is being aged over 40. For this purpose, we considered the possible influence of a number of factors on the respiratory system. These factors are the beginning of diving activity, the maximum depth reached, smoking, sports practice, and the presence of diving accidents.

MATERIAL AND METHODS

For this study, we worked with a sample of 23 male professional military divers, appointed at the CENTRO DE BUCEO DE LA ARMADA.

Previous to the performance of the spirometry, they answered a questionnaire which collected information on general sanitary aspects and specific information on their diving activity. On the general-health section we dealt with such diverse aspects as: current sanitary state, presence of any kind of allergy (especially allergic rinitis), smoking habits and sports practice. Subsequently, we went on to assemble the data related to their professional activity: first year of diving activity, maximum depth reached and presence of any type of diving accidents that had needed recompressive treatments.

As a measure instrument we used the portable manual spirometer VITALOGRAPH COMPACT, which was calibrated daily with a 3-litre-capacity syringe, the model being 5121 and its production standard number 121, A 655 (11). The process of calibration is carried out after warming the spirometer up. Prior to the performance of the spirometry, the subject is instructed in the methodology of the research, being informed about the ventilatory movements to be made, following SEPAR´s recommendations at every moment (15).

The spirometric variables studied were: FVC, FEV1, FEV1 / FVC, FEF 25-75, FEF 75-85. The independent variables used were: smoking, sports practice, years of diving experience, maximum depth reached and the presence of any diving accidents during their professional activity.

The statistical analysis was performed emplying Student´s t test for nonparametric samples, and using quantitative and qualitative variables. We considered as significant a value $p < 0,05$.

RESULTS

Previous to the detailed study of the different groups, established according to the variables studied, we shall expound the mean results and typical deviation of age, height and spirometric parameters of the 23 divers who took part in the study (table 1):

Subsequently, we expound the results according to the characteristics considered when preparing the study of this population:

1) Smoking habits:

In this group, all those individuals who had this habit at the time of the study, and those who stated having given it up for that last year, were considered smokers. Out of the 23 divers, 8 of them were smokers (34.78%) and 15 were nonsmokers (65.22%). The average values of each parameter are on table 2

2) Sports:

The results obtained show that 11 divers (47.82%) practise sports regularly (in this case aerobic exercises), jogging being the most practised one. On the contrary, the number of divers who don´t do any activity amounts to 12 (52.17%). Both groups´spirometric results can be observed on the table 3.

3) Beginning of their professional diving occupation:

We can find two groups: those with less than 20 years of professional activity (8 divers: 34.78%) as opposed to 15 (65.22%) with more than 20 years of diving experience. The results can be observed on the Table 4.

4) Maximum depth reached:

7 divers (30.43%) belonging to this group reached a depth equal or higher than 100 metres, whereas the remaining 16 (65.27%) did not surpass this depth (table 5).

5) Presence of diving accidents which required some kind of recompressive treatment: In this last group we find that 13 divers (56.52%) had some time needed some type of recompressive treatment, while the other 10 (43.48%) had not ever suffered any diving accident during their professional activity (table 6).

DISCUSSION.

As a conclusion from the data obtained, we can state that generally, divers present larger pulmonary volumes than expected for common population. This means that these subjects can voluntarily move big amounts of gas by each ventilatory movement. According to CALDER (2), this fact is due to hypertrophy of the respiratory muscles, as well as to an increase in the alveolar size. On the contrary, other authors such as THORSEN (20) and ELLIOT (10), consider the increase in lung capacities transitory. A more remarkable decrease in this parameter shall then take place, they affirm, when the diving subject has ceased professional activity.

Similarly, we observe that these individuals show less spirometric flows than expected. It can be due to obstructive changes in small airways, as a consequence of alveolar hypertrophy that is not accompanied by any increase in the diameter of the small airways (6). This hypertrophy can be caused by the combined action of diving practice and other accessory factors like smoking and inhalation of toxic substances and pollutants. ELLIOT (9) points out that the origin of such changes is the accumulative effect of high doses of oxygen when breathing at pressures higher than 0.3 bar.

Diverse studies have attemted to demonstrate the effect of smoking on divers′ pulmonary function. CIMSIT (5) revealed that there existed no significant relation between smoking and lung function in divers. Subsequently, DEMBERT (6) established that smoking caused a remarkable decrease in such parameters as FEV1 and midexpiratory flows. In our study, no relevant differences between smokers and nonsmokers show. However, we do observe how all spirometric parameters are higher in nonsmoking subjects than in smokers.

Irrespective of these results, smoking has various effects on pulmonary function which, added up to the effects of diving, make the professional activity of these subjects potentially dangerous:

a) Reduction in FEV1:

Whereas the normal decrease in this parameter is some 30 ml. per year (14), in smokers, the rate of decrease is increased because of their functional deterioration. In this way, decrease over 50 ml. per year in this parameter has led to think of a development of a chronic limitation on airflow (17).

b) Bronchial hyperreactivity:

This condition occurs in 32% of the smokers and in 21% of the ex-smokers, with a higher risk if associated with a decrease in FEV1 (13). The importance of this factor is stressed in TETZLAFF′s studies (18), and he establishes that an increase in airway reactivity with no specific cause is found in divers who bear a continuous exposure to diving. This situation of bronchial hyperreactivity, associated with a greater resistance of the airway during diving, increases the risk of air trapping and the possibility of the appearance of EAG (3).

c) Difficulty in the performance of physical exercises, owing to different factors: a rise in the intrabronchial resistance, which can even be 3 times higher than normal, being located in airways smaller than 2 mm. in diameter (12); difficulty in the gaseous exchange; and an increase in blood levels of CO_2. Some authors like ELLIOT (10) affirm the existence of divers who tend to retain greater amounts of CO_2, due to an inadequate ventilatory response. This circumstance does not cause negative effects in the long term, but acute hypercapnia can favour the appearance of neurotoxicity or appearance of DCI.

The limitation on airflow imposed by diving equipment is added to this situation of limitated physical activity of smokers. This shall complicate still further the performance of physically-demanding tasks to these individuals.

d) According to what DEMBERT (6) points out, there exists a relationship between smoking and the greater incidence of decompressive pathology.

As regards sports practice, we observe that the differences between sportsmen and nonsportsmen are not statistically significant. However, we find it necessary to comment that all spirometric parameters are higher in the sporting group than in the nonsporting. We recommend doing aerobic physical exercise in a progressive way and suitably according to age, as the use of diving apparatus requires greater effort from the respiratpry musculature. Divers must deal with this aspect in order to carry out a safe underwater activity.

The principal effects of physical activity upon respiratory system, from the point of view of underwater activity, are: decrease in respiratory work, given the improvement in the elasticity of pulmonary parenchyma, in proportion to the decrease in the resistance to airflow, as well as an increase in lung volumes and capacities which is to favour the process of pulmonary diffusion (12).

The beginning of diving activity is significantly modified in those parameters that show expiratory flows. This way, whereas the relation between FEV1 / FVC% ($p< 0.005$) and FEF 25-75% ($p<0.02$) stands out, other flow parameters such as FVC are not affected in a significant way. However, parameters like FVC show higher values, though not significant, in divers with over 20 years of professional activity. These results appear to indicate that, while pulmonary volumes stay the same or even increase in time, there takes place a situation compatible with an obstruction in small airways in divers with more professional experience. (1,16) Such other authors like DENISON (7) believe that decrease in those expiratory flows is not caused by an obstructive pathology, but by a lower distensibility and a higher tendency to collapse of the airway. THORSEN (19) establishes that one of the long-term effects of diving upon lungs is a decrease in elasticity of small airways.

Concerning maximum depth reached, we notice a significant change in all parameters that indicate obstructive situations of airways of different sizes Authors like THORSEN (19) consider that changes in lung function of divers who reach high depths are permanent and that it does not turn to normal once the diver has ceased professional activity.

An aspect which does not significantly influence on the diverse spirometric parameters studied is the presence or absence of diving accidents during divers´professional activity. In this way, it should appear logical to think that those individuals who undergo hyperabic treatment and therefore take high doses of oxygen for prolonged periods are to possess a more affected lung function.

As a conclusion to our study, we observe that divers aged over 40 years old show larger lung capacities than normal population, whereas parameters which indicate airway obstruction are decreased. This fact leads to consider the presence of an asymptomatic obstruction of small airways. Other parameters studied such as smoking and sports practice do not influence on these divers´pulmonary function, while two factors like the number of years of diving activity and maximum depth reached do significantly influence upon lung function in this group of divers.

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TABLE 1.- Age, Height and spirometric parameters (Mean value)

PARAMETER	VALUE	D.S.
AGE	44.21	3.19
HEIGHT	174.26	5.97
FVC	4.78	0.69
FVC %	104.87	11.66
FEV1	3.69	0.52
FEV1%	98.60	12.35
FEV1 / FVC%	77.52	4.43
FEF 25-75%	90.87	24.69
FEF 75 -85%	82.65	32.59

TABLE 2. Smokings habits (Mean Value)

Parameter	Smoker	D.S.	Nonsmoker	D.S.	PValue
FVC%	100.00	11.23	107.46	11.39	0.14
FEV1 %	95.37	9.53	100.33	13.61	0.37
FEV1 / FVC%	78.62	3.73	76.93	4.77	0.39
FEF 25-75%	88.75	17.23	92.00	28.38	0.77
FEF 75-85%	79.75	21.55	84.20	37.81	0.76

TABLE 3.-Sports Habits (Mean Values)

Parameter	No Sport	D.S.	Sport	D.S.	P Value
FVC%	101.75	12.27	108.27	10.44	0.18
FEV1 %	95.33	11.69	102.18	12.58	0.19
FEV1 / FVC%	77.50	4.07	77.54	4.98	0.98
FEF 25-75%	85.00	19.33	97.27	29.03	0.24
FEF 75-85%	73.83	22.63	92.27	39.73	0.18

TABLE 4.- Beginning of their professional diving activities (MeanValue)

Parameter	< 20 years	D.S.	> 20 years	D.S.	P Value
FVC%	104.62	8.53	105.00	13.31	0.94
FEV1 %	102.12	12.57	96.73	12.24	0.33
FEV1 / FVC%	80.87	4.12	75.73	3.53	0.005
FEF 25-75%	106.62	27.99	82.46	18.67	0.02
FEF 75-85%	98.00	42.94	74.46	23.25	0.10

TABLE 5.- Maximum depth (Mean Value)

Parameter	<100meters	D.S.	>100 meters	D.S.	Pvalue
FVC%	106.50	11.48	101.14	12.06	0.32
FEV1 %	101.81	11.39	91.28	12.05	0.05
FEV1 / FVC%	79.06	4.34	74.00	2.00	0.008
FEF 25-75%	99.75	21.91	70.57	18.54	0.006
FEF 75-85%	91.06	32.85	63.42	24.03	0.05

TABLE 6.- DIVING ACCIDENT (Mean Value)

Parameter	No accident	D.S.	Accident	D.S.	P Value
FVC%	107.27	12.72	102.66	10.67	0.35
FEV1 %	98.63	11.76	98.58	13.39	0.99
FEV1 / FVC%	75.81	3.89	79.08	4.46	0.07
FEF 25-75%	83.27	17.14	97.83	29.00	0.16
FEF 75-85%	76.63	20.66	88.16	40.83	0.4